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TOXIC SUBSTANCES

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The report speaks of toxic substances, specifically metals and their compounds and synthetic organic compounds. It briefly describes each substance and traces its path through the environment. Each substance's interaction with and effect on the environment is discussed. It deals extensively with technological and legal controls and suggests a new system for dealing with the problem

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by the Council on Environmental Quality
April 1971

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Environmental Quality: The First Annual Report
of the Council on Environmental Quality

Ocean Dumping: A National Policy

The President's 1971 Environmental Program

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Preface

In the spring of 1970, shortly after the Council on Environmental Quality came into being, we turned to the question of metals and synthetic organic chemicals which might endanger human health and the environment. It seemed that new controls were probably necessary to deal with the problems raised by such substances, but the scope of the problem, the lack of a central source of knowledge to deal with questions raised, and the great uncertainty about a number of key aspects of the whole area of toxic substances led us to the conclusion that extensive staff work would be necessary prior to a decision about the desirability or content of possible legislation. This report is the result of that work.

The data collection, analysis, and much of the writing of the report were substantially complete by December 1970. However, the process of formulating the President's legislative program overtook the task of finishing the report. Thus the proposed Toxic Substances Control Act of 1971 became public before the study upon which the legislation was based.

The Council is grateful to the many individuals who contributed to preparation of this study. We are particularly indebted to Dr. John Buckley and Dr. Edward Burger of the President's Office of Science and Technology, Dr. Henry Kissman of the National Library of Medicine, and Dr. Douglas Worf and Dr. Delbert Barth of the Environmental Protection Agency. We hope that this report will help to shed light on the President's proposed legislation and that it will contribute to understanding of a major environmental problem.

RUSSELL E. TRAIN, *Chairman*
ROBERT CAHN
GORDON J. MACDONALD

Findings and Recommendations

The Council on Environmental Quality has examined the problems associated with toxic substances in the environment and has reached the following conclusions:

Toxic substances are entering the environment

About 2 million chemical compounds are known, and several thousand new chemicals are discovered each year. Most new compounds are laboratory curiosities that will never be produced commercially. However, several hundred of these new chemicals are introduced into commercial use annually. Of particular concern because of their rapidly increasing number and use are the metals, metallic compounds, and synthetic organic compounds.

U.S. consumption of metals with known toxic effects has increased greatly in the last 20 years. The data on use underestimate the increasing pervasiveness of metals in our environment because many new metallic compounds are being formulated and used in an ever widening variety of new products.

Similarly, use of synthetic organic chemicals is growing rapidly. Over 9,000 synthetic compounds are now in commercial use in amounts of over 1,000 pounds each per year. In 1968, they totaled nearly 120 billion pounds—a 15 percent increase over 1967 and a 161 percent increase over 10 years ago.

Although many of these substances are not toxic, the sheer number of them, their increasing diversity and use, and the environmental problems already encountered from some indicate the existence of a problem.

These substances enter man's environment—and man himself—through complex and interrelated pathways. Present in air, water, soil, consumer products, and food, they pervade our environment. They often become concentrated through the food chain—with minute quantities being magnified thousands of times as they are consumed by higher forms of life. Increasingly, all forms of life are being exposed to potentially toxic substances.

These substances can have severe effects

The environmental effects of most of the substances discussed in this report are not well understood. Testing has largely been confined to their acute effects, and knowledge of the chronic, long-term effects, such as genetic mutation, is inadequate. Although far from complete, available data indicate the potential or actual danger of a number of these substances.

Many serious effects, including those resulting in cancer (carcinogenicity), genetic mutations which cause permanent and transmissible change in the genes of offspring from those of the parent (mutagenicity), and production of physical or biochemical defects in an offspring (teratogenicity) can occur from metals, their compounds, and synthetic organic compounds. In general, we do not know which chemicals cause such effects or the levels that a given chemical must reach before the effects occur.

The problem is complicated by the chemical changes which may occur once toxic substances enter the environment. They can become more toxic through modification in the ecosystem or as a result of synergistic actions with other substances.

Wildlife and fish populations are also being exposed to these substances, and some species have already been severely damaged by such exposure.

Existing legal authorities are inadequate

Existing Federal Government controls over the introduction of toxic substances into the environment are of two types. The first is control over the initial production of a substance and its distribution. For example, under the Federal Insecticide, Fungicide, and Rodenticide Act, a manufacturer must register a pesticide with the Environmental Protection Agency

(EPA) before it can be introduced in interstate commerce. EPA can prohibit distribution of a pesticide or require labeling of acceptable uses. This type of control, exercised at the point of manufacture, is also applied to drugs and food additives. Although this control technique can be very effective, current authorities cover only a small portion of the total number of potentially toxic substances and do not deal with all uses of a substance which may produce toxic effects. Most of the substances mentioned in this report are not subject to the legal controls necessary to protect man from the toxic effects noted.

The second type of control is media oriented and thus is directed at air and water pollution from various sources. Federal authority derives primarily from the Clean Air Act and the Federal Water Pollution Control Act. Under the Federal Water Pollution Control Act, the Federal Government, in cooperation with the States, sets standards for the amounts of particular substances allowable in the water. Under the Clean Air Act, the Federal Government sets national air quality standards, allowing the States to set more stringent standards. Enforcement of standards depends on limiting the emissions of a substance from a given source.

In theory, this type of authority can be used to control the substances discussed in this report, but there are several limitations to the effective application of such controls. These media-based authorities are mainly concerned with pollutants which occur in large quantities. Controlling minute quantities of dangerous substances is difficult with this type of authority, in part because of the difficulty of detecting their presence in air or water. Control is also difficult because many toxic substances enter the environment through disposal of consumer products. If a product is disposed of by flushing into a municipal sewer line or by burning at an incinerator, it is almost impossible for the media-oriented controls to deal effectively with the toxic decomposition products which might result. For example, if there were a need to control a substance contained in a household detergent, under the media authorities the government could try to limit the amount of the substance emitted from municipal waste treatment plants. But such a limit would be effective only if the substance could be removed by existing treatment methods, and many toxic substances cannot be so removed.

Most toxic substances are not exclusively air or water pollutants but can be found in varying quantities in air, water, soil, food, and industrial and consumer products. The multiplicity of ways by which man can be exposed to these substances makes it difficult for the media-oriented authorities to consider the *total* exposure of an individual to a given substance, a consideration necessary for the establishment of adequate environmental standards. Also, in the past no agency has considered itself completely responsible for all such substances in all media. The likely result is what happened in the case of mercury: Available knowledge on adverse effects was ignored and new data were not collected.

New legal authority is required

The Council's study indicates the high-priority need for a program of testing and control of toxic substances. Our awareness of environmental threats, our ability to screen and test substances for adverse effects, and our capability to monitor and predict, although inadequate, are sufficiently developed that we need no longer remain in a purely reactive posture with respect to toxic substances. We should no longer be limited to repairing the damage after it has been done; nor should we continue to allow the entire population or the entire environment to be used as a laboratory.

To assure this protection without handicapping desirable technological innovation or hindering interstate commerce, the Council on En-

vironmental Quality recommended new legal authority.

In February 1971, the President submitted to the Congress a bill based on these recommendations. The Toxic Substances Control Act of 1971 calls for several major, new authorities:

- The Administrator of the Environmental Protection Agency would be empowered to restrict or prohibit the use or distribution of a chemical substance if such restriction were necessary to protect health or the environment. In imposing such a restriction, the Administrator would be required to consider not only the adverse effects of the substance but also the benefits to be derived from its use.
- If the Administrator believed that a substance were creating an imminent hazard, he could ask the courts to restrain use or distribution of the substance immediately.
- The Administrator would be authorized to issue standards for tests to be performed and for results to be achieved from such tests for various classes and uses of new substances. A new substance (excluding products covered by other regulatory authority) could be marketed only after it met these standards.
- The Administrator could request information from the manufacturers on potentially toxic substances—names, chemical composition, production level, uses, and results of tests conducted on their effects.
- The Council on Environmental Quality would be charged with coordinating efforts to establish a uniform system for classifying and handling information on chemical substances.

The proposed legislation also authorizes the Administrator of EPA to carry on needed research on toxic substances and to develop an information system and prediction capability to deal effectively with these materials.

Such an information system would focus on the quantity, distribution, and flow of a particular substance throughout the environment. Focusing on the pollutant rather than on the particular medium being polluted has two major advantages: First, a potential problem can often be rapidly identified, perhaps before damage to health or the environment has occurred. Second, this approach can suggest the most efficient means of controlling a problem. If the analysis indicates that most of a substance is entering the environment through water, then the most efficient control may be through water pollution control laws. If an identified industrial or consumer use of a substance is responsible for the major amount of environmental contamination, then control of the distribution and use of the substance may be the most efficient strategy. In short, pollutant-focused monitoring is capable of giving the decision-maker the overall view necessary for making key enforcement decisions.

For the system of testing, monitoring, and control authorized in the proposed legislation to be most effective, the scientific basis of much of our research must be greatly improved. First, a broader view of the problem must be taken. In terms of human health, *total* exposure of a human being to a given substance from all parts of his environment—air, water, and food—must be considered, and the interactions of these substances both within and outside the body must be evaluated. Similar consideration must be given to other living organisms.

Second, testing substances for their effects on man and the environment must be expanded, and the scientific basis for interpreting such tests must be improved. Current scientific knowledge about data gained from experiments with animals is often inadequate to allow reliable interpretation of the data in terms of possible effects on man.

Much effort has already been devoted to toxic substances monitoring and research. Much more will be needed. The proposed legislation would improve the framework for such efforts, but by itself it would not bring them to fruition. The

resources of the Environmental Protection Agency, the Department of Health, Education, and Welfare, industry, universities, and many others both within and outside the Government will be necessary to achieve a truly adequate system for assessing the hazards of toxic substances and for preventing damage from them.

SUMMARY

Recent incidents of mercury and other contamination of the environment and the diversity and quantities of toxic and potentially toxic substances entering the environment indicate the extent of this growing national problem. Action is needed to prevent damage to man's health and the environment. New regulatory authority, improved research, and better monitoring systems have been recommended and must be implemented now if protection is to be provided.

The approach called for in the Toxic Substances Control Act is a new way of looking at environmental problems. Rather than dealing with pollutants as they appear in air, in water, and on land, it represents a systematic and comprehensive approach to the problem. It relies on understanding the flow of potentially toxic substances throughout the entire range of activity—from extraction to production to consumer use and to disposal. Only through such a comprehensive approach can we provide protection to man and his environment. In the last few years, we have identified the enormity of the problem; we have developed the institutional capability through the creation of EPA to look comprehensively at pollution of the environment. The time has come for an action program to control the use of toxic substances.

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CHAPTER 1 *Scope and Magnitude of the Problem*

Until recently, the public and the Government have been concerned with pollutants which appear primarily in one medium, usually air or water. These pollutants—such as suspended solids, particulates, and sulfur oxides—generally occur in large, measurable quantities. They can be readily identified with existing monitoring techniques, and legal authority for their control is available. Controlling their levels in the media in which they primarily occur protects human health and the environment. However, there are substances, such as radioactive materials and pesticides, for which research, monitoring, and control based on media are not adequate. In the case of radioactive materials and pesticides, needed regulatory authority and control procedures have been developed.

There are several types of substances for which no adequate control authority exists and for which a total environmental approach is lacking. Existing authority based on media control, although sometimes applicable, is not adequate to deal with such substances because they are present not only in our air, water, and soil but in all the products that we consume and use in our everyday lives. Further, control of a substance in one medium often shifts pollution to another medium. For the protection of man and his environment, all sources of exposure must be considered comprehensively. Chapter I examines major examples of the toxic chemical substances for which this comprehensive approach is needed and indicates the extent of the problem presented by them.

Everything in our environment is composed of chemical substances, and most of these pose minimal danger to man or the environment. However, some pose a serious danger—particularly those produced by man's activities. Those chemicals which damage the environment are usually called pollutants. Not all pollutants are of concern as toxic substances. Most common air and water pollutants, such as particulates and solids, are not included in the Council study because existing regulatary authority and control programs adequately deal with them. For this reason, radioactive substances, drugs, food additives, and pesticides are also excluded.

Many other chemical substances are of concern here because of their potentially toxic effects at extremely low levels of exposure and their presence in many media. Rather than attempt to be exhaustive given our current incomplete knowledge, this report indicates the problem by using examples of what appear to be the most pressing areas of concern.

Selected metals, their compounds, and certain synthetic organic chemicals are perhaps the best examples of toxic substances which can adversely affect man and his environment. They enter the environment in a variety of ways, through air and water and through food and other goods. In this chapter, the magnitude and pervasiveness of the problem are indicated by the quantities of potentially toxic substances produced and the variety of products in which they are found. The pathways by which these substances enter the environment and their potential for adverse effects are outlined in Chapter II. Chapter III describes existing and proposed control measures for such substances.

METALS AND THEIR COMPOUNDS

Singly or in combination, the 105 known elements form the basis of all matter. Of these, 77 are metals. Simply stated, metals are elements generally characterized by ductility, malleability, luster, and conductance of heat and electricity. Of the 77 elemental metals, 52 can be considered "economic metals," that is, they are in sufficient industrial and commercial usage to warrant collection of statistical production data. The quantities used vary from millions of tons for iron and manganese to only thousands of ounces for iridium. (*44*)

Many, perhaps most, metals are prerequisite

to life, usually in trace amounts. However, some metals and/or their compounds can and do adversely affect human health if ingested or absorbed in excessive quantities. A necessity of life at certain levels, they can be lethal at increased levels.

Serious adverse environmental and/or health effects, actual and potential, have been observed or indicated for roughly one-fourth of the metals in common economic usage today. Many of the troublesome metals are the so-called "heavy metals," of which lead and mercury are the most common examples. Table 1 shows the estimated U.S. consumption of selected metals for which adverse human effects have been documented. Not included in these estimates are data for production and release of metals from processes other than those used to produce the metals for consumption. For example, Table 1 does not include the amounts of vanadium released to the atmosphere from oil combustion or of mercury released from coal combustion.

TABLE 1.—*Estimated U.S. Consumption of Selected Metals, 1948 and 1968 (44, 45)*

Metal	Total estimated consumption[1] (in tons)		Percent increase 1948–1968
	1948	1968	
Arsenic (AS_2O_3)	24,000	◇25,000	◇4
Barium (barite)	894,309	1,590,000	78
Beryllium (beryl)	1,438	8,719	507
Cadmium	3,909	6,664	70
Chromium (chromite)	875,033	316,000	80
Copper	1,214,000	1,576,000	30
Lead	1,133,895	1,328,790	17
Manganese (ores, 35% or more Mn)	1,538,398	2,228,412	45
Mercury	1,758	2,866	63
Nickel	93,558	159,306	70
Selenium	419	762	82
Silver[2]	3,611	4,983	38
Vanadium	[3] N.A.	5,495	
Zinc	◇1,200,000	1,728,400	44

[1] Includes stocks released to the open market by the Federal Government and imports; does not include exports.

[2] Consumption by industry and arts; monetary consumption not included because much was stockpiled.

[3] Figures not available between 1946 and 1955; consumption in 1946 was about 748 tons, in 1955 about 1 700 tons.

After originally extracting metals from the earth, man reintroduces them into the environment directly in elemental form or in a wide variety of compounds. The compounds may have quite different effects from their elemental forms; some metals are more toxic as compounds.

The compounds of metals appear in larger number than do the metals themselves as intermediate and consumer products. For example, at least 40 lead compounds and more than 45 cadmium compounds are currently in commercial use. (*3, 23*) The total number of variants for just two of these metals is thus more than five times the total number of metals for which adverse effects have been identified. Most of the other metals are also used in a wide array of compounds.

Numerous manufacturing processes and products employ metals and their compounds. Arsenic, for example, is used in the manufacture of glass, pigments, textiles, paper, metal adhesives, ceramics, linoleum, and mirrors. (*39*) Its compounds are used in wood preservatives and paints, insecticides and herbicides, and electrical semiconductors. Beryllium is used in several of the above manufacturing operations as well as in electroplating and as a catalyst in organic chemical manufacture. Barium is used in paper manufacturing, fabric printing and dyeing, embalming, synthetic rubber production, and animal and vegetable oil refining. It is a component of fireproofing compounds, x-ray screens, water softening chemicals, enamels, lubricants, and photographic supplies. (*27*)

These products exemplify the diversity of uses of metals and the almost unending list of products in which they may be present. When metals are used in the manufacture of products, effluents from the operations often contain metallic compounds, which may contaminate the environment. When metals are present in final products, direct human contact or environ-

mental exposure is possible during use or after disposal.

The number of metals and related compounds for which serious environmental concerns arise will probably increase as technology continues to find new uses for existing metals and metallic compounds. The increasing consumption of metals is shown in Table 1.

New products will require the development of new metal compounds and possibly the expanded use of metals which now have little, if any, commercial use. Iridium, once only a laboratory curiosity, is now used to make jeweler's platinum and to manufacture electric instruments, penpoints, surgical instruments, and needles. (*40*) Beryllium has been used experimentally in rocket fuels. These new variations and applications are certain to increase the potential exposure of man to metals.

SYNTHETIC ORGANIC COMPOUNDS

The Chemical Abstracts Service Registry Number System has registered some 1.8 million chemical compounds, and the list is growing by the addition of 250,000 chemicals each year. (*2*) Approximately 300 to 500 new chemical compounds are introduced annually into commercial use. (*42, 43*) Of those which are or may be used commercially, synthetic (manmade) organic chemicals are of special concern because frequently they are alien to the natural environment, and in some instances their modification, redistribution, or persistence have already had some dangerous effects.

Approximately 9,000 synthetic organic compounds were in commercial use by 1968. (*47*) As shown in Table 2, production is increasing rapidly, from over 103 billion pounds in 1967 to nearly 120 billion pounds in 1968, an increase of about 15 percent. Compared to the 1957–1959 annual average of 46 billion pounds, production increased 161 percent in approximately 10 years. (*47*) With changes in industrial needs and technological knowledge, new and more complex compounds with new and different uses are constantly being developed.

TABLE 2.—*U.S. Production of Synthetic Organic Chemicals, 1968* [1] (*47*)

Chemical	1968 Production (in millions of pounds)	Percent increase over 1967
Intermediates	25,014	20.3
Colorants:		
Dyes	226	9.7
Pigments	54	1.9
Flavors and perfumes	117	4.5
Plastic products:		
Plastics and resins	16,360	18.6
Plasticizers	1,331	5.4
Rubber products:		
Processing chemicals	313	18.6
Elastomers	4,268	11.6
Surface active agents	3,739	7.5
Miscellaneous	67,525	13.1
Total	118,947	15

[1] Includes data on production measured at several successive steps in the manufacturing process and therefore reflects some duplication.

Public disclosure is not permitted by the data-collecting agency when only one manufacturer produces a chemical. When production of an item was below 1,000 pounds, or sales below $1,000, a product is not included. Further, medicinals and pesticides are not included.

The synthetic organic chemicals shown by classes in Table 2 are obtained from coal, crude petroleum, natural gas, wood, vegetable oils, fats, resin, and grains. Products are formed by such processes as thermal decomposition, synthesis, catalytic cracking, distillation, absorption, or fermentation. Intermediate products are sometimes consumed directly or may be further processed. The category of intermediates in Table 2 refers to those that are consumed directly.

Dyes and pigments are organic chemicals used to impart color to other materials. Approximately two-thirds of the over 1,000 synthetic dyes consumed in the United States per year is used in coloring natural and synthetic fibers

or fabrics, and about one-sixth is used in coloring paper. (*48*) The remainder is used chiefly in the production of organic pigments and in dyeing plastics and leather. Pigments are used in paints and related products, in printing inks, and in plastics and resin materials.

In some cases, pigments contain metals in addition to their organic constituents. Dyes and pigments, a part of many everyday products, find their way into the environment from manufacturing operations as well as from ultimate disposal of consumer products.

Plastics and associated resins and additives, such as plasticizers, are another major type of synthetic organic chemical. Plasticizers are organic chemicals that are added to synthetic plastics and resin materials to improve workability during fabrication; to extend or modify the natural properties of these resins; or to develop new, improved properties not present in the original resins. They are present in plastic products in concentrations ranging from less than 5 to as high as 50 percent. Polychlorinated biphenyls (PCB's), a class of compounds formerly used in small amounts as plasticizers, are of considerable environmental concern.

Total U.S. production of plastic products in 1968 was 17.7 billion pounds, 103 percent more than in 1962. (*47, 49*) By 1980, total plastics production is expected to be well over 50 billion pounds, with production growth at about 10 percent per year through the coming decade. (*41*)

Plastics are used in ever increasing quantities to replace other materials. Packaging, previously dominated by glass, paper, and metals, now employs large quantities of plastics. In some cases plastics have replaced the traditional packaging materials. When used with other materials, plastics have improved such features as strength and appearance.

Polyethylene, polyvinyl chloride, polystyrene, and ABS (acrylonitrile-butadiene-styrene) resins were first used as packaging in the 1950's. Volume usage developed about 1960. By 1966, 2.2 billion pounds of plastics were used in packaging, and by 1976, the figure is expected to reach almost 6.3 billion pounds, a 185 percent increase. (*3*) The use of plastics is also increasing dramatically in other areas. Relatively new is use in automobiles, shoes, handbags, coats, furniture, dishes, and insulation.

Rubber products can be manufactured from synthetic organic chemicals (elastomers) which are formulated with properties similar to natural rubber. Products made from natural rubber may contain synthetic organic chemical additives. Hence, these types of synthetic organics are commonly found in toys, tires, rain coats and shoes, carpet backing, garden equipment, tools, and numerous other products.

Surface-active agents, another category of synthetic organic chemicals, reduce the surface tension of water or other solvents and are used chiefly in detergents, dispersing agents, emulsifiers, foaming agents, and wetting agents. A major portion—about 550 million pounds—is used in detergents for both household and industrial use. (*36*) The remainder is employed in processing textiles and leather and in the manufacture of agricultural sprays, cosmetics, elastomers, lubricants, paints, pharmaceuticals, and many other products.

Organic chemicals can be tailored in structure and properties to fit almost any imaginable need. During 1968, production of chemicals in the miscellaneous category shown in Table 2 totaled 67,525 million pounds, over half of all synthetic organic chemicals produced. Examples of chemicals in this category are some of the halogenated hydrocarbons, which are used as solvents in dry cleaning and refrigerants, and aerosol propellants for hair sprays, paints, and deodorants. Alcohols, nitrogen compounds, acids and anhydrides, aldehydes, and ketones are also included in this category.

SUMMARY

Man's physical environment is now exposed to a myriad of potentially toxic substances. These substances are the constituents of nearly everything that man uses. In trace amounts in the human body, some are essential to life; yet in larger quantities these same substances may be toxic. The balance between these two extremes is often unknown. And because of man's own activities, other substances not formerly present are now found in the human body.

The uses of chemical substances are growing rapidly, many new substances are being formulated, and new commercial applications are being found almost daily. As Chapter II indicates, many of this growing array of substances have already been found to have adverse effects on man and his environment.

CHAPTER II *Environmental Pathways and Effects*

Chapter I discusses toxic substances, their quantities, and the diversity of products in which they are present. This chapter examines how these substances enter the environment, move within the system, and ultimately affect man and other organisms.

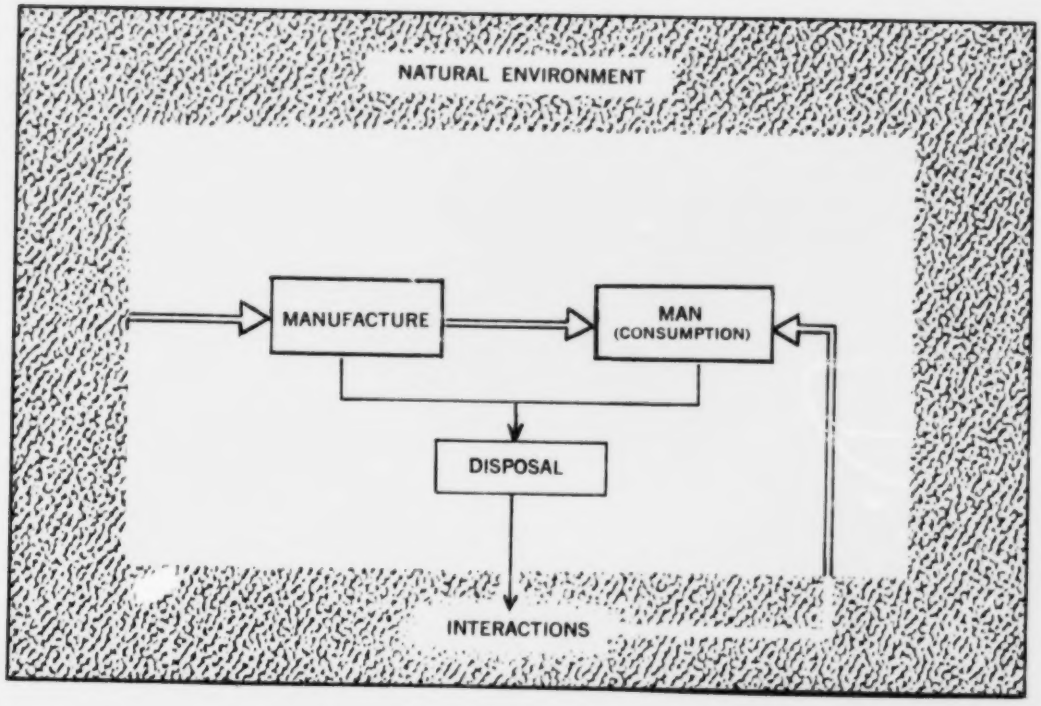
PATHWAYS OF ENVIRONMENTAL CONTAMINATION

Figure 1 is a simplified diagram of how potentially toxic materials reach man and his environment. It indicates several key processes: First, materials are extracted from the environment in crude form and are successively refined, processed, and manufactured into more diverse and complex forms ("Manufacture" in Figure 1). These diverse processes may produce air and waterborne wastes to which man may be exposed at each intermediate step. The wastes can contain not only the original substance but also considerably modified and perhaps more toxic substances. The end products are consumed by man as food or are used as durable and nondurable goods. This consumption and use can result in man's further exposure to a substance.

Consumption, however, is not the end of most

FIGURE 1.

PATHWAYS FOR TOXIC SUBSTANCES



products, because after they have served their purpose, they must be disposed of. Except for direct recycling, disposal methods return material to the environment—but almost always to a different place and often in different chemical form. Thus, the disposal process alters the patterns of distribution and concentration of substances which naturally occur in the environment and may produce new chemical forms which may be more dangerous to man than the original substance. As a result of disposal processes, assimilation by biological organisms may be facilitated, interaction with other chemical substances may occur, and inherent toxicity may be enhanced. These possibilities are suggested by "Interactions" in Figure 1.

There is a natural background of metal substances and compounds in the environment to which biological systems generally have adapted over the millenia. It is the redistribution and chemical alteration resulting from man's activities when he engages in economic exploitation and disposal which are considered here. Although some substances introduced by man into the environment may represent a net benefit, for example, small amounts of fluoride in water to reduce tooth decay, this report is concerned with possible adverse effects.

Both metals and synthetic organic chemicals are potential environmental hazards. However, significant differences exist in the ways in which the two types of substances enter the environment and affect man.

Metals are recovered from ore deposits either directly or as byproducts in the course of refining other metals. Pure cadmium, for example, is not found uncombined in nature in commercially usable quantities. Commercial quantities are obtained as a byproduct of smelting zinc. (*3*)

During the mining and refining processes, dusts and gases enter the atmosphere. Metallic salts formed during these recovery and refining processes can escape as waste products into surface and ground water. Undesirable concentrations of metals and metallic salts in the environment have been reported from such sources in a number of cases, including:

- High concentrations of cadmium salts in Missouri mine waters—in one spring the concentration was 1,000 milligrams per liter (*25*)
- High atmospheric vanadium concentrations near mining and refining operations (*4*)
- Toxic levels of arsenic trioxide emissions from a gold mine and smelter in the western United States. (*39*)

Almost all synthetic organic compounds are manufactured from crude petroleum, natural gas, and coal rather than from raw ores. Although extraction and transportation of the raw materials cause some environmental damage, the more complex synthetic compounds produced by manufacturing operations are often the most toxic.

Waste effluents often result from the manufacture of synthetic organic chemicals. These effluents may be the compounds which remain unreacted in the production process or the unwanted byproducts of the operation. Sludges, gases, and liquid effluents of varying chemical complexity and toxicity may be produced. For example, thermal cracking of crude petroleum to obtain gasoline or fuel oils can yield phenols, sulfides, and other organic wastes. Ammonia, mercaptans, and waste oil effluents result when reforming is used to produce benzene, toluene, and other products.

Finally, the diverse end products reach man and are used. In the course of use, some toxic materials may inadvertently be introduced into the environment. One example is the unburned or partially burned hydrocarbons from gasoline. Eventually, most unused residues must be disposed of, and they enter the environment through sewage systems, incineration, or landfill.

Most sewage treatment plants are not capable of removing many of the toxic substances found

in waste water. Secondary sewage treatment is capable of removing a large portion of the metals, but many synthetic organic chemicals are unaffected by the biological treatment processes employed by municipalities. Even if the toxic substances are removed by treatment, their presence in sewage sludge may still pose a problem.

About 10 percent of all municipal solid wastes are incinerated. During combustion, organic and metallic materials are converted into a multitude of compounds. Some are partially oxidized or reduced and their structure and properties substantially changed. Some remain unaltered chemically, changing only physically, as from a solid to a gas. Some gaseous or particulate products of combustion are drawn off through the stacks; those that are not removed by stack gas cleaning reach the atmosphere. The solid residue from combustion is often quenched with water, which then enters the general environment. Eventually most airborne emissions return to earth and are deposited on land and in water.

Materials disposed of at some landfills also can present a problem. At landfills the volume of wastes is frequently reduced by open burning. The resultant particulate and gaseous emissions can cause the same pollution problems encountered in incineration. Even when the wastes are buried, leaching of toxic metals or organic compounds is possible, causing contamination of ground or surface water. For example, the plasticizers in plastics may be leached and thus contaminate ground water supplies. (*14*) Regardless of the pollution which may result, disposal of metals and some chemicals in landfills represents a waste of valuable resources which could be recycled.

Another possible method of disposal is to dump wastes in the ocean. The Council issued a previous report on this subject and concluded that available methods of land disposal are preferable to ocean dumping. (*6*)

INTERACTIONS WITHIN THE ENVIRONMENT

After substances enter the environment, they may be diluted or concentrated by physical forces, and they may undergo chemical changes, including combination with other chemicals, that affect their toxicity. The substances may be picked up by living organisms which may further change and either store or eliminate them.

The results of the interaction between living organisms and chemical substances are often unpredictable, but such interaction may produce materials that are more dangerous than the initial pollutants. One example is inorganic mercury, which was thought to settle safely into the bottom sediments when discharged into water. Anaerobic bacteria are now known to convert inorganic mercury into very toxic and soluble organic mercury compounds, such as methylmercury, which pass through the food chain by aquatic algae and by fish, eventually reaching man. (*37*)

DDT, another example, is nearly insoluble in water. It occurs in high concentrations among some fish-eating birds as a result of two factors: DDT's solubility in fats is much higher than in water, and plankton, shellfish, and fish generally pass successively higher concentrations of DDT on to the organism next in the food chain. Polychlorinated biphenyls (PCB's), which are chemically similar to DDT, have been found in similar association with marine food chains. Oysters exposed to one type of PCB for 96 hours accumulated the substance to a level 3,300 times that of the ambient water. (*9*)

Synergism is another complicating interaction. Two or more compounds acting together may have an effect on organisms greater than the sum of their separate effects. For example, the toxic effects of mercuric salts are accentuated by the presence of trace amounts of copper. (*46*) Cadmium acts as a synergist with zinc and

cyanide in the aquatic environment to increase toxicity. (*20, 25, 32*) Conversely, sometimes the presence of one substance lessens the effect of another substance on an organism. Arsenic, a toxic substance itself, counteracts the toxicity of selenium and has been added to poultry and cattle feed in areas where animal feeds are naturally high in selenium. (*38*)

EFFECTS OF TOXIC SUBSTANCES

As noted earlier, metals, unlike synthetic organic compounds, have always been present in the environment, and living organisms—including man—have evolved in their presence. Blood and body tissues are composed of a complex mixture of elmental substances, including the metals. Some metals are essential to life at low concertrations but are toxic at higher concentrations. Further, the form in which the metal occurs—as a pure metal, an inorganic metallic compound, or an organic metallic compound—strongly influences its toxicity. Thus the danger of metals to man depends on their concentration and chemical form.

Most synthetic organic substances are not essential to life, though many share with metals the characteristic of toxicity. As with metals, the concentration and type of exposure to a particular synthetic organic substance are key factors in determining its effects.

The total effect of all toxic substances on a single species, say, man, is impossible to quantify with accuracy because of our lack of knowledge about the effects of toxic substances. Although many substances in the environment can cause death or injury if man is exposed to them in sufficiently high concentrations, the effects of long-term exposure to low levels of such substances, singly or in combination, are generally unknown. A standard text on the dangers of commercial products rates the toxicity of more than 1,000 commercially used chemical compounds, most of which are toxic to man at high levels of exposure. (*13*) However, the long-term effects of iow levels are known for only a few.

Although lack of effort partially accounts for this paucity of knowledge, our ignorance also stems from the many difficulties inherent in testing for adverse effects. The large number of chemicals that should be evaluated by long-term laboratory experiments requiring many test animals is a serious limiting factor. Extrapolation of data on dose effects obtained from animal studies to man must consider many species variations in response to exposure from toxic substances. Substances rarely occur in the environment in isolation, so that possible synergism or antagonism of two or more substances adds to the difficulty of adequate testing and of interpretation of field results.

Difficult choices must also be made in determining the effects or biological end points to be examined. Biological end points are often determined from such irreversible effects as carcinogenesis, mutagenesis, and teratogenesis.

Carcinogenesis is the ability of a substance to cause cancer. Chemical mutagenesis is the induction in protoplasm of genetic mutations by a substance. These can be permanent and transmissible changes in the genes of an offspring from those of the parents of earlier generations. Teratogenesis is the production of physical or biochemical defects in an offspring during gestation; it is limited to a particular child. During the last decade, there were many deformed infants born of women who had ingested the drug thalidomide during pregnancy—a vivid example of teratogenesis.

The effects of any given substance may vary among individuals and among species. Differences in effects are a function of age, sex, health condition and history, stress, different metabolic patterns in different species, and other less understood factors. Further, we often do not know how to apply to humans the results

from experiments with laboratory animals. If a substance produces cancer in mice, will it produce human cancers? How do we extrapolate the level of a substance required to produce a given effect in mice to the level that will produce the same effect in man? If mice are not affected by a substance, is that substance also safe for humans?

All these difficulties contribute to the dearth of knowledge concerning the biological effects of many environmental contaminants and particularly the toxic substances discussed in this report. But we do understand enough to know that many substances may significantly threaten man and the environment.

Many useful data on health effects of toxic substances derive from studies of occupational exposure. Commonly, the levels of exposure are much higher at the workplace than in the total environment, and the data gathered on exposed groups of workers can contribute to understanding effects on the general population. However, even here caution must be exercised in interpreting the results for nonindustrial groups who are exposed to lower concentrations and whose level of health may not match that of the industrial worker.

A few examples will illustrate the ways in which toxic substances have become a part of our environment and have affected humans. These examples are not in any way intended to be exhaustive or definitive. All of the limitations cited above concerning data on effects apply to the examples, and the data given are used simply to illustrate, in a selective way, the basis for concern over toxic substances.

Metals and Their Compounds

The potential for dangerous metals' entering the environment is indicated by the consumption data in Chapter I. Studies of ambient conditions substantiate these data: Twenty-seven trace elements are found in the atmosphere. (*33*) A survey of eight heavy metals in U.S. waters showed that these metals were distributed in low concentrations. (*10*) Their level in drinking water generally did not exceed standards but did indicate potential problems in some areas.

Examples of the toxic effects of metals are readily found. Compounds of nickel and beryllium, which accumulate in the lungs, may cause fatal diseases. (*33*) If inhaled, barium can cause respiratory disease, or if ingested in sufficient quantities, it causes heart, intestinal, and nervous system disorders. (*27*)

Some laboratory experiments indicate that exposure to metals may interfere with vital chemical reactions. In a study of rats and mice living in a carefully controlled environment relatively free from metal contamination, the sample group lived 20 to 25 percent longer than the control group in its usual contaminated environment. (*33*) In addition, laboratory breeding mice exposed to concentrations of cadmium, lead, or selenium produced abnormal offspring. Long periods of arsenic and molybdenum exposure changed the sex ratios of mice and rat offspring. Antimony, in low doses, shortened the lifespan of rats. (*33*)

Lead—Lead is one of the oldest known pollutants. In the second century B.C., the wealthy class of Rome was decimated by sterility, child mortality, and permanent mental impairment. (*12*) According to one theory, this decline can be traced to lead poisoning from wine and food vessels. The lower classes survived because they could not afford lead utensils.

Today lead is absorbed by humans in a more democratic way, because all social classes are exposed to lead in the atmosphere. Lead particles in the air eventually settle to land and water, mixing with other sources of the metal and following complex pathways in the environment. The increase in lead pollution is now global in scope. For example, between 1904 and 1964, lead concentrations in Greenland snow increased 16-fold. (*28*)

A variety of industrial and mining effluents, disposal of consumer products such as automobile batteries, and various food products all contribute to both environmental and human accumulation of lead. However, these sources are small contributors to lead pollution compared with combustion of leaded gasoline. In 1968 alone, 180,000 tons of lead were emitted from leaded-gasoline combustion—14 percent of all lead consumed in the United States that year. (*11*)

Although the acute toxicity of lead has been a health problem for 2,000 years, the effects of ambient levels are not known. Acute poisoning is still a frequent problem, primarily among children who have eaten chips of lead-based paint in older dwellings. The use of lead-based paint is now restricted, but there are still many old houses whose walls are covered with lead paint applied years ago. Aside from this problem, the critical question today is whether the total body burden produced by inhaling air polluted with lead and by drinking water containing small amounts of lead is sufficiently large to produce any adverse effects. The data are not conclusive, but in the opinion of at least one recognized expert, "There is little doubt that at the present rate of pollution, diseases due to lead toxicity will emerge within a few years." (*33*)

Cadmium—Like most metals, cadmium is stable and does not degrade in the environment. Thus, as increasing amounts of cadmium are refined, more and more of it is circulated in the environment, and increasing amounts may reach man.

Only a fraction of the cadmium taken into the body is actually absorbed by the body. The cadmium which is absorbed accumulates in the kidneys and the liver, and because there appears to be an inefficient excretory mechanism in humans, accumulation tends to increase with increased absorption.

The effects of such accumulation vary according to the amount and time period of exposure. Some preliminary studies indicate that exposure to low levels of cadmium from sources present in the everyday environment may lead to hypertension and heart disease and perhaps to cancer. (*5, 30, 34*)

Many sources contribute to the accumulation of cadmium in humans. The metal is found in concentrations of 50 to 170 parts per million in superphosphate fertilizers, and it is also used in some pesticides. (*3*) Cadmium becomes an air and water pollutant through a variety of industrial processes, and it is being used in increasing amounts by the storage battery, plastics, plating, and petroleum industries. Additional amounts are introduced into the home by the pipes which carry drinking water. (*33*) Food is another major source of cadmium—it has been found in a variety of products, from dry cereal to vermouth. (*29*)

Mercury—Although poisoning from mercury has been recognized as an occupational hazard for years, concern with mercury as a general environmental contaminant in the United States is quite recent.

Metallic mercury was long thought environmentally inert. When discharged into a river, for example, it was believed to settle to the bottom and remain there. Then in 1960, it was reported that 111 persons had died or suffered serious neurological damage near Minamata, Japan, as a result of eating fish and shellfish which had been contaminated by mercury discharged into Minamata Bay by a plastics manufacturing plant. (*1*) In 1965, another poisoning incident was reported in Niigata, Japan, and in 1966, Swedish studies indicated that many species of birds were being poisoned by mercury. (*18*) Other Swedish studies pinpointed the critical facts that metallic mercury, previously thought inert, can be changed by bacteria into methylmercury—a compound that is far

more toxic than metallic mercury—and that methylmercury can enter the food cycle through uptake by aquatic plants, algae, lower forms of animal life, and fish. (*17, 21*) Even more significantly, the studies showed that the concentration factor in the fish could be 3,000 or more to 1. (*18*) Thus, harmless levels of mercury in water can be concentrated to hazardous levels in fish.

In 1967, large amounts of methylmercury were reported in fresh-water fish in Sweden. (*21*) A study submitted in the same year to the U.S. Public Health Service concluded: "From our review of mercury as an environmental chemical contaminant, it is obvious that a considerable amount of mercury has been cycled through our environment. . . . We have little or no information as to where the mercury that is being cycled through our environment is going." (*24*) The report recommended expanded monitoring and study of the health effects of mercury.

Finally, in the spring of 1970, high levels of mercury were discovered in fish in Lake St. Clair, on the Canada–U.S. border. Canada banned the sale of fish from the Lake, and 10 days later Michigan followed suit. In succeeding months, there followed a series of bans, mostly of fish and seafood products containing, or suspected of containing, excessive mercury. These actions resulted in losses of millions of dollars to the food, canning, and tourist industries.

The concern over mercury is well founded. Some organic mercury compounds are accumulated in humans, concentrating in the brain, the kidney, the liver, and the fetus. They can destroy the cells of the brain, cause tremors and mouth ulcers, and produce birth defects because of chromosome breakage. (*19*)

The sources of mercury are numerous. It is used in a number of industrial processes and appears in such varied products as paints, electrical apparatus, thermometers and other instruments, and cosmetics. Primary concern has focused on mercury as a water pollutant, largely because it is now known to reach the food chain by water, but the metal is also present in soil and in air.

Vanadium—Very little research has been done on the toxicity of environmental concentrations of vanadium. When the route of exposure is the respiratory tract, vanadium may accumulate in the lungs. High concentrations of the metal may damage human gastrointestinal and respiratory tracts. (*4*) Exposure to lower concentrations has resulted in inhibition of cholesterol synthesis in man. (*4*)

Trace amounts of vanadium are natural to all humans, but it is probably a recent addition to the atmosphere. There is no evidence that ambient levels of vanadium are toxic. But these levels have been increasing in recent years due to the burning of fuel oils containing vanadium and to increased industrial use of vanadium compounds. Eighteen compounds of vanadium are now used in a wide variety of commerical processes. (*24*)

Synthetic Organic Chemicals

A vast number of synthetic organic chemicals is being introduced into the environment, and many of these chemicals have not been identified. A study prepared for the Water Quality Office of the Environmental Protection Agency reported that 496 organic chemicals were found or suspected in fresh water, but the chemical composition of only 66 of these was identified. (*22*) The disparity between the number recorded and the number identified indicates the need for better monitoring and analytical techniques. It also shows the difficulty of dealing with such substances once they have entered the environment.

Some organic compounds have been identified as tumor-producing in experimental animals.

A smaller number have been singled out as capable of causing cancer in humans. Research on teratogenic effects has been limited, but a few chemicals have been shown to be teratogenic in humans in doses corresponding to those which might be expected in the environment. So little testing has been conducted on the mutagenic effects of synthetic organic chemicals that almost nothing is known about such effects.

Discussed below are three example of synthetic organic chemicals which have posed some hazard to human health or the environment.

NTA (Nitrilotriacetic Acid)—NTA recently came into extensive use as a substitute for phosphates in detergents. Until a couple of years ago, almost no NTA was used. NTA, a substance with which the consumer has suddenly come into direct contact, may enter the general aquatic environment in large quantities through flushing into sewers and septic tanks. If NTA proved safe, an estimated 600 million pounds would have been used annually in detergents by 1973. (*36*) Because of its concern with water pollution caused by detergents, the Federal Government studied the health and environmental effects of NTA and other phosphate substitutes. Preliminary results indicated that NTA may combine with cadmium, mercury, and other metals to enhance the toxicity of these metals. Therefore, the major detergent manufacturers recently agreed not to use NTA until completion of testing now underway.

ONCB (Orthonitrochlorobenzene) (*26*)—ONCB is an unusable byproduct in the manufacture of paranitrochlorobenzene, a chemical in wide commercial use. In 1958, this unique and persistent chemical was found at levels of .021 parts per million in water samples taken at monitoring stations between St. Louis and New Orleans. Concentrations of 0.03 parts per million of ONCB were found in treated drinking water, indicating that ONCB survived normal potable water treatment procedures. Few studies have been done on the effects of ONCB, but it was calculated that 5 to 50 parts per million would be lethal to humans and that 0.5 to 5 parts per million would cause clinical symptoms.

Although concentrations of ONCB in the water were not toxic, the Public Health Service concluded that the safety factor was not adequate, the chemical was remarkably persistent, and normal water treatment was inadequate. On the basis of this analysis, the source of the ONCB agreed to remove waste streams containing ONCB from the river.

PCB's (Polychlorinated Biphenyls)—The molecules of plastics are generally inert and nonreactive. Problems arise because of certain types of plasticizers, dyes, oxidation retardants, and various stabilizers which are added to plastics. These additives are not always chemically bound to the plastic molecules and thus may be released into the environment. PCB's, also known as Aroclors, are such a group of additives.

PCB's are among the more persistent organic chemicals—they degrade very slowly in the environment. In addition to their use as plasticizers, they have also been used in paint, electrical transformers, and lacquer resins and as lubricants, heat transfer fluids, and "carriers" for some insecticides. Structurally, PCB's resemble DDT, and like DDT, they are not soluble in water but are fat soluble and therefore can be absorbed by human tissue. The resembiance to DDT goes further. PCB residues have been found in fish and wildlife around the world. Normally used analytical methods find it difficult to differentiate between DDT and PCB's.

In April 1969, PCB's were first detected as residues in oysters in Escambia Bay, Florida. Further sampling indicated the presence of PCB residues in the water, sediment, fish, blue crabs, and shrimp. The substance was traced to a leak from an industrial plant 6 miles upstream

from the Bay. PCB was being used there as a heat exchange fluid, and the leak was not known. The leak has been stopped, but PCB's are still present in the Bay, albeit in decreasing amounts, apparently leaching from river sediments. (*9*)

Tests with PCB's have shown that 0.1 parts per million were fatal to juvenile pink shrimp after a 48-hour exposure, and the same concentrations stopped oyster shell growth in 96 hours. In laboratory tests, shrimp, pinfish, and oysters all concentrated PCB. (*9*) U.S. Fish and Wildlife Service workers have correlated the lethal effects of PCB's on game birds directly with the chlorine content of PCB. (*15*)

PCB's have also been found in Great Lakes fish and in human fatty tissue. (*31*) A study of human tissue samples showed concentrations of from less than 1.0 parts per million to as high as 250 parts per million. Fifteen percent of the samples exceeded 1.0 parts per million PCB's. (*31*) Another study showed that over half the urban residents examined had traces of PCB in their blood. (*11*)

SUMMARY

This chapter discusses the many pathways by which toxic substances enter the environment. Such substances are found in air, water, soil, food, and a variety of consumer products. Once they enter the environment, complex changes can take place which can alter their chemical form and change the ways in which they affect man.

The effects of toxic substances on man vary according to the type of substance, the amount of the substance to which a person is exposed, the duration and method of exposure, and several other factors. There is ample evidence that many metals and synthetic organic chemicals can pose hazards to human health.

Effects on human health are the primary concern of this chapter. Effects on wildlife, agriculture, and other parts of the ecosystem pose additional problems, but the effects of toxic substances on ecosystems have been even less well explored by scientists than the effects of such substances on man.

CHAPTER III *Technological and Legal Controls*

This chapter details methods for controlling the introduction of toxic substances into the environment. Technological controls are discussed as background for evaluation of institutional and legal authorities available.

TECHNOLOGICAL METHODS OF CONTROL

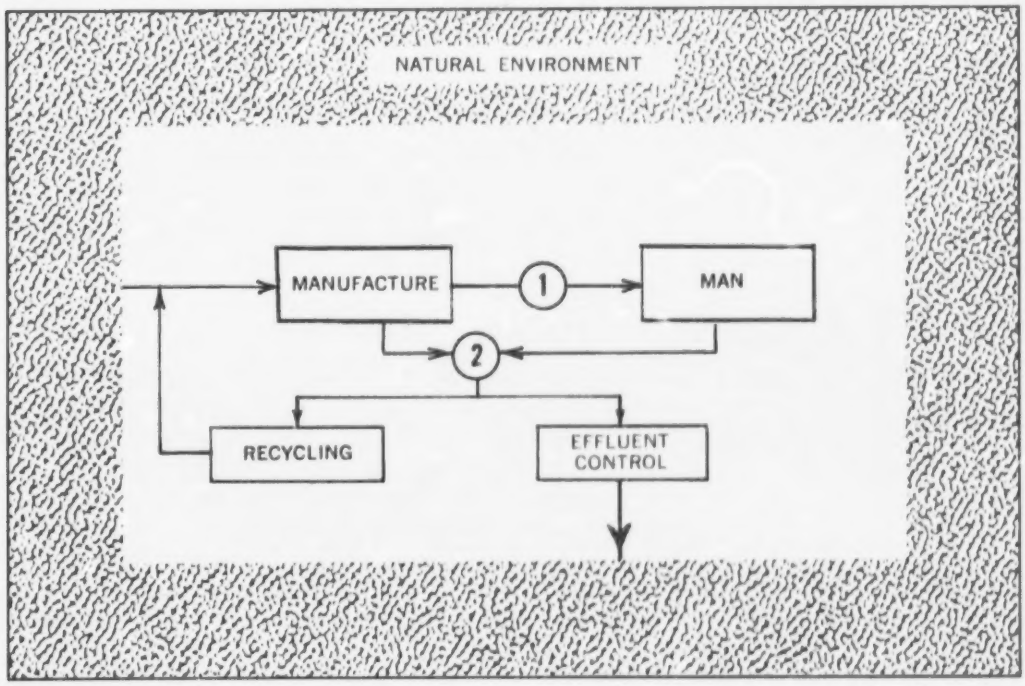
Several control strategies exist for almost all the substances included in this study because each enters the environment in numerous ways. The strategies are of two general types: control of a product and its uses, including total prohibition of the product, and control of the effluents. The alternatives and their relationship to the pathways by which contaminants enter the natural environment are shown in Figure 2. Each is discussed briefly.

Product Control

Control of products ("1" in Figure 2) to reduce contamination of the environment can be effected by either reducing the input of the raw material of concern or changing the nature of the end products.

FIGURE 2.

CONTROL STRATEGIES FOR TOXIC SUBSTANCES



From a materials balance analysis, reducing the amount of a contaminant that is initially used ultimately reduces the amount that can enter the environment from effluents, regardless of the number or complexity of intermediate steps. Also, to the extent that the total body burden for a given substance or its accumulation in a target organ is important, this control point may be the easiest at which to determine the absolute reduction required.

For example, fuel oils contain varying concentrations of metals. In the future we may have to look to fuels with low concentrations of highly toxic metals, just as we look to low-sulfur fuels today. Fuel oil combustion is chiefly responsible for vanadium concentrations in the atmosphere. Residual oil imported from Venezuela has up to 63 percent vanadium pentoxide in ash, compared with 14 to 38.5 percent for oil from Iran and 0.4 percent, 1.4 percent, and 5.1 percent for oil from Kansas, Texas, and California, respectively. (*35*) Changing to low-vanadium fuel is a control that could be used to reduce atmospheric vanadium concentrations if such reduction were necessary.

Changing end products or prohibiting their production is an important control technique because man is directly affected by these products and by their disposal—through interaction with the environment and through further interaction with man. Simply changing an ingredient can also effect a desired change. For example, lead has been used in paint to accelerate drying; its harmful effects can be eliminated by removing it from the product formulation and substituting another less toxic or nontoxic material.

Certain plastic products have used plasticizers which were persistent and upon disposal could cause damage to wildlife. Replacing them with other materials has alleviated the disposal problem without robbing the product of desired physical characteristics.

Control over use of a product is often successful in reducing or eliminating damage caused by the product. The circumstances under which products such as drugs or pesticides can be used are carefully regulated because of the severe damage which can result if they are misused. Many toxic substances can be used safely if human exposure is prevented. For example, the manufacturer of PCB's agreed to limit their use to closed systems, thus preventing damage by preventing their entering the environment.

Effluent Control

A second method of controlling the introduction of pollutants into the environment is to change the production process to eliminate or to control the effluents.

Changes in production processes may, in some cases, significantly reduce the quantities of contaminants that are discharged as effluents or that become intermediate or final products. For example, improving the efficiency of synthetic organics production can reduce the volume of toxic or potentially toxic effluents. Yields of organic products are rarely, if ever, 100 percent. Remaining chemical constitutents are usually wastes, which may be recovered, treated, or released to the environment. Hence, to the degree that production is made more efficient and more of the raw material is utilized, wastes released to the environment are reduced.

Similarly, changes in production processes can change byproducts or wastes to less toxic or less persistent compounds. Some carcinogenic organic compounds are produced by burning coal and refuse. Improving combustion efficiency lowers the concentration of the carcinogens emitted.

Controlling effluents from manufacturing processes and from end product disposal has been the most widely used technique for controlling pollutants. The processes used are re-

cycling, waste treatment, or other kinds of disposal.

When the contaminants are of high value, as some metals are, recycling not only protects the environment but may also be the major source of the mineral. For example, arsenic, cadmium, and selenium occur in such low natural contrations that they are not mined for themselves but are recovered during the refining of lead and zinc, among other metals. Similarly, because mercury is expensive, much of it can be economically recovered from effluents for reuse.

Recycling synthetic organic chemicals is more difficult than recycling metals and their compounds due to their complex molecular structures and to the economics of recovery. However, recycling rather than disposal is sometimes possible. Instead of incinerating scrap plastics, some scrap can be remelted for reuse in fabrication.

Treatment of wastes is also useful in preventing the harmful interaction of contaminants and the environment. Arsenic, nickel, and vanadium are usually airborne contaminants resulting from smelting other metallic ores. These toxic substances are commonly emitted with particulates. Therefore baghouse filters, wet scrubbers, and electrostatic precipitators which remove substantial quantities of particulates also reduce emission of these toxic metals. The resultant ash and metals can then be carefully disposed of or recycled. For example, an electrostatic precipitator which effectively reduces particulate emissions also reduces arsenic concentrations from a range of 5 to 17 parts per billion before treatment to 0 to 4 parts per billion after treatment. (*39*)

Effluents can also be neutralized before final disposal. Metals converted to metallic salts or sulfides can be disposed of more safely. Also, some potentially toxic synthetic organics can be treated. Before disposal, phenols—a byproduct of some synthetic organic processes—can be decomposed by biological action into carbon dioxide and water, two harmless, natural chemical components.

EXISTING LEGAL CONTROLS

Legal authorities available to control pollution parallel the technical methods of control. A product is controlled by regulating the amount manufactured and the uses permitted. For some products the processes of manufacture are regulated. Effluent control has generally involved the establishment and enforcement of standards for levels of air or water pollutants.

Product Control

The Federal Government exercises some control over the manufacture and distribution of pesticides, drugs, food additives, consumer products, and radioactive materials. Each of these authorities differs somewhat from the other.

Pesticides are regulated under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (7 U.S.C. 135–135k), enacted to protect the user and handler of pesticides by requiring registration, proper labeling, and in some cases coloring of pesticide products. The FIFRA regulates the marketing, in interstate commerce, of "economic poisons and devices," which includes insecticides, rodenticides, plant defoliants, and household disinfectants.

The FIFRA requires registration of pesticides with the Administrator of the Environmental Protection Agency (EPA). The manufacturer must submit data to establish the safety and efficacy of a pesticide along with the label proposed for the product. This information is reviewed to determine that the label contains adequate directions for use and adequate warnings to assure that handling, storage,

or use of the product will not result in injury or damage when used as directed. Through the registration procedure and its approval of labeling, EPA can control whether a pesticide will be marketed and, if marketed, the particular crops on which it will be used. There is no provision for control over application of the pesticide, but the Administration has submitted a new, comprehensive pesticides bill which would remedy this and other defects in the existing law. The Food and Drug Administration (FDA) also enforces pesticide regulations through examination of food to insure that the pesticide residues do not exceed allowable limits.

FDA, under the authority of the Food, Drug, and Cosmetic Act (21 U.S.C. 301 et seq.), regulates food labeling, food additives, food containers, drugs, and cosmetics. Particularly tight controls are exercised over drugs. Before they are marketed, drugs must be registered and approved by FDA. They must be properly labeled and must be safe and effective when used as directed or suggested. Drug producers must register their plants, which are subject to close inspection by FDA. Manufacturers and handlers of depressant or stimulant drugs must keep extensive records of the type, quantity, and disposition of such drugs.

Regulation of foods, food additives, and cosmetics is less stringent. Food standards can be prescribed for identification, quality, and fill of containers. New food additives must be cleared prior to use. FDA can prohibit the use of particular food additives or establish tolerance levels for the amount to be used. Although preclearance is not required for cosmetics, they must not contain poisonous or deleterious substances; they cannot be produced or held in unsanitary conditions or packaged in a container which renders the contents injurious to health; and they must be fairly and accurately labeled.

Radioactive materials are the most closely regulated of all substances. Under the authority of the Atomic Energy Act of 1954, as amended (42 U.S.C. 2011 et seq.), the Atomic Energy Commission (AEC) regulates almost the entire spectrum of activity associated with the handling, transportation, and disposal of radioactive materials. Specifically, the AEC licenses and maintains continuing surveillance over facilities utilizing, processing, or disposing of radioactive materials. It also prescribes procedures and standards for packaging and shipping such materials.

Effluent Control

There are two major statutory authorities for controlling the release of pollutants directly into the environment—the Federal Water Pollution Control Act (33 U.S.C. 466 et seq.) and the Clean Air Act (42 U.S.C. 1857 et seq.). Both have been extensively amended since enactment, and the Congress is now considering further major changes in the Water Pollution Control Act.

The Federal Water Pollution Control Act provides for establishment of Federal–State water quality standards for interstate and coastal waters. Standards for all States have been approved by the Federal Government, although standards for some interstate waters and some measures of quality have not yet been established. These standards basically cover general parameters of the water—such as oxygen content, temperature, and turbidity—rather than specific substances in the water. Although the standards may be enforced directly by the Federal Government, primary responsibility for enforcement rests with the States.

Early in 1970 and again in 1971, the Administration submitted to the Congress amendments to the Water Pollution Control Act designed to broaden the Act's coverage and to simplify the enforcement process. The amendments would

extend the coverage of water quality standards to all navigable waters, ground water, the contiguous zone, and the high seas with respect to discharges emanating from U.S. territory; and they would authorize establishment of effluent standards for all such waters. The Government also recently announced a program based on the 1899 Refuse Act, which requires a Federal permit to discharge effluents other than municipal sewage. The Refuse Act authority will serve as the basis for a national system of controlling industrial pollution.

The Clean Air Act has provided for a system of Federal–State establishment of air quality standards. However, comprehensive amendments to the Act (Clean Air Amendments of 1970 (Public Law 91–604)) passed recently require the Federal Government to establish national air quality standards and require the States to submit emission standards for individual pollutants for Federal Government approval. Further, the amendments require Federal establishment and enforcement of emission standards for certain classes of new industry and for hazardous air pollutants.

In addition to air and water pollution control, the Federal Government is concerned with solid waste disposal. However, the Solid Waste Disposal Act (42 U.S.C. 3251–3259) and the amendments contained in the Resource Recovery Act of 1970 (Public Law 91–512) do not authorize Federal regulation but deal primarily with research and demonstration of improved methods of disposal. The Resource Recovery Act does require the formulation of a plan for a system of national disposal sites for the storage and disposal of hazardous wastes. Many State and local governments promulgate disposal regulations, but in the main the regulations are concerned with visible smoke, not with toxic substances. No laws or regulations are directed at the problems which may be created by the disposal of potentially toxic materials.

Toxic Substances

Existing law does not entirely ignore the types of substances dealt with in this study. Toxic substances are specifically dealt with in the Hazardous Substances Act (15 U.S.C. 1261–1273), section 12 of the Federal Water Pollution Control Act (33 U.S.C. 1162), the recent amendments to the Clean Air Act, and the authorities of the Department of Transportation relating to transportation of hazardous substances.

The Hazardous Substances Act covers household products and toys—but not the raw materials from which they are manufactured. Thus it does not deal directly with most of the toxic substances of concern in this report. Primarily the law authorizes the Secretary of Health, Education, and Welfare only to require how a product should be labeled. Although the Act does allow extremely hazardous products to be banned from interstate commerce, the definition of a "hazardous substance" is quite restrictive, stating that a substance may be banned only if special labeling or packaging is found ineffective in preventing a hazard. Only three household products have been banned.

Section 12 of the Federal Water Pollution Control Act authorizes the President to designate hazardous substances and to recommend methods and means for their removal from water. Under the section (33 U.S.C. 1162(a)), "hazardous substances" is limited to "such elements and compounds which, when discharged in any quantity into or upon the navigable waters of the United States or adjoining shorelines or the waters of the contiguous zone, present an imminent and substantial danger to the public health or welfare . . ." The section is generally aimed at accidental discharges of such substances into water and thus does not cover either continuous discharges into water or release of hazardous substances into other media.

The Clean Air Amendments of 1970 contain a section directed specifically at hazardous substances and also authorize the Administrator of EPA to regulate the use of fuel additives. Section 112 requires the EPA Administrator to publish a list of air pollutants which are not covered by air quality standards and which "may cause, or contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness." The Administrator must then set and enforce national emission standards for these pollutants. A similar section has been included in the Administration's proposed amendments to the Water Pollution Control Act.

The Department of Transportation (DOT) regulates interstate transportation of hazardous substances under several authorities, including the Department of Transportation Act (49 U.S.C. 1651 et seq.), the Transportation of Explosives Act (18 U.S.C. 831–837), and the Hazardous Cargo Act (46 U.S.C. 170). DOT has defined several classes of hazardous materials (49 C.F.R. Parts 170–179), and its Hazardous Materials Regulations Board plans further classification based upon health hazard (35 Fed. Reg. 8831, June 6, 1970). Although some testing for effects of hazardous substances is involved in the implementation of these regulations, substances are classified primarily from the perspective of hazards involved in their transportation and possible spills from accidents. Most of the problems of toxic substances discussed in this report relate to aspects of their use rather than to transportation and spills.

Inadequacy of Authorities

It is clear that current laws are inadequate to control the actual and potential dangers of toxic substances comprehensively or systematically. The controls over manufacture and distribution pertain to only a small percentage of the chemical substances which find their way into the environment. Almost all the effects described in Chapter II relate to substances not covered by present controls over manufacture and distribution.

Both controls over production and controls over effluents suffer from the limited focus of their authority. For example, the Food and Drug Administration carefully examines food containers for their effect on food but does not address the environmental and health effects of incinerating the containers. With the exception of radioactive materials, disposal is not a consideration in any programs controlling manufacture.

But the problems of focus are broader than specific examples. Setting rational standards for many pollutants under existing legislation is almost impossible. The key factors involved in setting standards are the *total* human exposure to a substance and its *total* effect on the environment. The focus must be on a particular pollutant and all the pathways by which it travels through the ecosystem. Controls over distribution approach this perspective, but most fail to consider important environmental factors adequately.

The obvious limitation of controls over effluents is that they generally deal with a problem only *after* it is manifest. They do not provide for obtaining information on potential pollutants before widespread damage has occurred.

More subtle but more serious limitations of effluent controls arise from their focusing on the media—air or water—in which the pollution occurs. This approach has several consequences: First, it leads to concern with those substances found in air or water in the greatest quantities. For example, the Air Pollution Control Office uses the gross weight of air pollutants as one indicator of the severity of air pollution. Gross weight is a valid indicator, but it disregards

the degrees of danger of the various pollutants. As indicated in Chapter II, comparatively small amounts of some substances can cause severe damage, but media-oriented programs tend to overlook the importance of such substances. Another consequence of the media approach is that it cannot deal effectively with the fact that many, perhaps most, toxic substances find their way into the environment through several media. They cannot be characterized strictly as water pollutants or as air pollutants, for they are found in air, in water, and often in soil, food, and other parts of the environment. The characteristic pervasiveness of toxic substances makes it difficult for the media-oriented programs to engage in adequate and efficient research, monitoring, and control activities for such substances. The need for such a comprehensive approach was a major rationale for the creation of the Environmental Protection Agency (EPA).

The scope of EPA's authority provides a basis for an integrated approach to toxic substances. However, such an approach cannot be accomplished simply by coordinating the activities of existing media-oriented programs. The activities themselves must be conducted on an integrated basis. Testing to determine the health or environmental effects of a substance must be done in terms of total exposure to the substance, not simply exposure through air or through water. There must exist a capability for integrating the monitoring data from various media and for doing nonmedia analyses, for example, utilizing the materials balance approach. (This approach compares the total amount of a substance produced with the amount appearing in various end uses. A disparity between the two indicates the approximate amount escaping into the general environment.) Finally, there must exist authority to insure that the effects of a new substance are carefully examined before it enters the air, soil, or water.

A NEW SYSTEM

The shortcomings of the legal authorities described above, the effects of toxic substances outlined in Chapter II, their increasing number and amounts indicated in Chapter I, and the inadequate attention paid to such substances all support the need for a new legal and institutional system to deal with toxic substances.

Our awareness of environmental threats, our ability to screen and test substances for adverse effects, and our capabilities for monitoring and predicting, although inadequate, are now sufficiently developed that we need no longer remain in a purely reactive posture with respect to chemical hazards. We need no longer be limited to repairing damage after it has been done; nor should we allow the general population to be used as a laboratory for discovering adverse health effects. There is no longer any valid reason for continued failure to develop and exercise reasonable controls over toxic substances in the environment.

In February 1971, the Administration submitted to the Congress a bill developed by the Council on Environmental Quality in consultation with EPA and other agencies, entitled The Toxic Substances Control Act of 1971. The bill contains two new, major authorities:

- The Administrator of the Environmental Protection Agency would be empowered to restrict or prohibit the use or distribution of a chemical substance if such restriction were necessary to protect health and the environment. In imposing such a restriction, the Administrator would be required to consider not only the adverse effects of the substance but also the benefits to be derived from use of the substance, the normal circumstances of use, the degree to which release of the substance or its byproducts to the environment is controlled, and the magnitude of human and environmental exposure to the substance or its byproducts.

- The Administrator would be authorized to issue standards for tests to be performed and for results to be achieved from such tests for various classes and uses of new substances. A new substance could be marketed only after it met these standards. Consumer products (insofar as their household use is hazardous), pesticides, drugs, and other kinds of substances which are already regulated would continue to be regulated under existing authorities rather than under the Toxic Substances Act.

In addition to these two authorities, the bill contains several other significant provisions. If the Administrator believed that a substance were creating an imminent hazard, he could ask the courts to restrain use or distribution of the substance immediately. The Administrator would be authorized to develop the resources necessary to predict introduction of new chemical substances into the environment and to assess the environmental consequences of their introduction. The Council on Environmental Quality would be charged with coordinating efforts to establish a uniform system for classifying and handling information on chemical substances. The bill would also establish an independent Toxic Substances Board to provide scientific advice to the Administrator of EPA.

EPA would also be given authority to collect information on potentially toxic substances, an authority vital to a successful program for dealing with such substances. The Administrator could request information from manufacturers on the substances that they produce—names, chemical identities, amounts produced, uses, and results of tests conducted on their effects.

SUMMARY

Existing legal authorities are inadequate to deal with toxic substances. If a substance is toxic, control must often be exercised at the point of manufacture and distribution because the variety of ways in which such substances enter the environment and the difficulties of detecting many of them make effluent controls an ineffective mechanism. Also, standard setting, monitoring, and control can often be done more efficiently and rationally if attention is focused on the particular substance rather than on the medium in which it may appear.

The proposed Toxic Substances Control Act represents a significant step in dealing with problems that will become increasingly acute unless action is taken. The growing number and amount of substances produced commercially are an environmental problem of potentially great magnitude. The proposed legislation and accompanying administrative action would protect the public and the environment to a far greater degree than is now possible.

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